Waves	Intensity

Learning objectives	MUST (6)	Define the intensity of a wave
	SHOULD (7)	Describe and justify the inverse square law
	COULD (8/9)	Explain the relationship between intensity and amplitude, and carry out calculations

STARTER: If Earth moved to half its usual distance from the Sun, how would the Sun's light intensity on each square metre of the Earth's surface change? Would it increase by a factor of...
a) √2, b) 2, c) 4, d) 8

EXTENSION: Justify your answer above, thinking carefully about the energy the Sun emits.
Extra thinking question: how old would you become?

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The square of the orbital period of a planet is proportional to the cube of the semimajor axis of its orbit. Earth's new orbit, at 0.5 AU, would have an orbital period of 0.35 of our current Earth years. Each of our current years would be 2.83 new years. You'd be (2.83 x 17) = 48 'new' years old.

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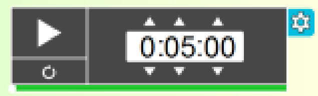
The intensity of a wave is defined as the radiant power passing through a surface per unit area.

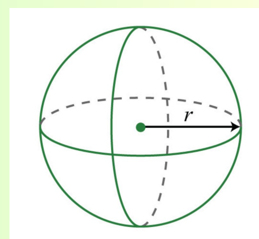
$$I = \frac{P}{A}$$



Intensity = radiant power/area: what are the units of intensity? W/m^2

Deriving the inverse square law

Imagine a source of radiant power, such as a star. How does the radiant power spread out over time?



The radiant power spreads out as a sphere.

The total power at a distance r from the star is spread over....

the surface area of a sphere with a radius r, so the area is $4\pi r^2$.

At this point, the intensity is $P/4\pi r^2$.

What if we now consider the power at a distance 2r?

The intensity will be $P/4\pi(2r)^2$, or $P/4\pi(4r^2)$ = $P/16\pi r^2$

Distance from source	Intensity	Intensity compared to distance r
r	$P/4\pi r^2$	1
2r	$P/16\pi r^2$	1/4
4r	$P/64\pi r^2$	1/16

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The intensity drops off at $1/r^2$, if r is the distance.

Mini-plenary:

Earth's distance from the Sun is 150M km

Mars' distance from the Sun is 230M km

What will the intensity of the Sun on Mars be, compared to the intensity on Earth?

If Earth's distance is r, then Mars' distance would be (230/150) = 1.53r.

Intensity drops off at $1/r^2$, or $1/1.53^2$, = approx. 43%.

Waves	**Intensity**
COULD (8/9)	Explain the relationship between intensity and amplitude, and carry out calculations

If you double the amplitude of a wave, you quadruple its intensity. $I \propto \text{amplitude}^2$

(thinking question: can you have negative amplitude? can you have negative energy?)

When you double the amplitude of a wave at the same frequency, the speed of the oscillations must increase (think about the point at the zero crossing - it must move at twice the speed) and so therefore must the kinetic energy: $0.5mv^2$.

1 State what happens to the intensity of a wave when the amplitude:
a increases by a factor of 3; **b** decreases by a factor of 4. *(2 marks)*

2 Calculate the intensity when a power of 400 W is received over a cross-sectional area of 20 m^2. *(2 marks)*

3 Calculate the intensity 20 m from a source of light with a power of 60 W. *(3 marks)*

4 Figure 4 shows the cone of light created when light passes through a converging lens. Describe and explain how the intensity of light changes from A to B. *(4 marks)*

5 A satellite in orbit around the Earth uses two solar panels for power. The intensity of sunlight received at the height of the satellite is $1.4\,\text{kW m}^{-2}$. The surface area of each solar panel is $8.0\,\text{m}^2$. Calculate the total energy transferred to the panel in a period of 2.0 hours. *(4 marks)*

6 At a distance of 15 m from a point source the intensity of a sound wave is $1.0 \times 10^{-4}\,\text{W m}^{-2}$.
a Show that the intensity 120 m from the source is approximately $1.6 \times 10^{-6}\,\text{W m}^{-2}$. *(3 marks)*
b Discuss how the amplitude of the wave has changed. *(2 marks)*

1 a Intensity increases by a factor of 9 (3^2).
b Intensity decreases by a factor of 16 (4^2).

2 $I = \frac{P}{A}$

$I = \frac{P}{A} = \frac{400}{20} = 20\,\text{W m}^{-2}$

3 $I = \frac{P}{4\pi r^2}$

$I = \frac{60}{4 \times \pi \times (20)^2}$

$I = 12\,\text{mW m}^{-2}$ (2 s.f.)

4 From $I = \frac{P}{A}$ if the power is constant

then: $I \propto \frac{1}{A}$

As the area reduces

Intensity increases.

5 Intensity = $1.4\,\text{kW m}^{-2}$ therefore power received by each $8.0\,\text{m}^2$ panel is: $1400 \times 8.0 = 11\,200\,\text{W}$

Total power received = $11\,200 \times 2 = 22\,400\,\text{W}$

$P = \frac{W}{t}$ therefore $W = Pt$

$W = 22400 \times 7200 = 160\ \text{MJ}$

6 a $I = \frac{P}{4\pi r^2}$ therefore $P = I \times 4\pi r^2$ [1]

$P = 1.0\times10^{-4} \times 4 \times \pi \times (15)^2 = 0.28\ \text{W}$ (2 s.f.) [1]

$I = \frac{P}{4\pi r^2}$ therefore the intensity at 120 m

$= I = \frac{0.28}{4\times\pi\times120^2} = 1.6 \times 10^{-6}\,\text{W m}^{-2}$ (2 s.f.) [1]

b Intensity has fallen by a factor of 65. [1]

As intensity $\propto (\text{amplitude})^2$ the amplitude will have decreased by a factor of 8.1 ($\sqrt{65}$) (2 s.f.) [1]

Oct 16-21:59

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PLENARY:

A stone is dropped into water, and ripples spread outwards. Do you think that the inverse-square law applies? Why, or why not? What have you assumed?

Extension: what about a noise travelling through air?

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